Deficiency of Broad Line AGNs in Compact Groups of Galaxies

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ABSTRACT

Based on a new survey of AGN activity in Compact Groups of Galaxies, we report a remarkable deficiency of Broad Line AGNs as compared to Narrow Line AGNs. The cause of such deficiency could be related to the average low luminosity of AGNs in CGs: 10^{39} erg s^{-1}. This result may imply lower accretion rates in CG AGNs, making Broad Line Regions (BLR) undetectable, or may indicate a genuine absence of BLRs. Both phenomena are consistent with gas stripping through tidal interaction and dry mergers.

Subject headings: galaxies: active — galaxies: Seyfert — galaxies: nuclei — galaxies: evolution

1. Introduction

From the optical spectra of AGNs, one can generally distinguish two main types: those that show broad emission lines (BLAGNs) and those that show only narrow emission lines

(NLAGNs). With an absolute magnitude $M_V \geq -23$, the local BLAGNs are called Seyfert 1 (Sy1), while the NLAGNs are called Seyfert 2 (Sy2). In the literature, one can also find other types of Seyfert galaxies: Sy1.2, Sy1.5, Sy1.8, and Sy1.9, all of them being some sort of Sy1 and consequently BLAGNs. NLAGNs may also come into the form of Low Ionization Nuclear Emission-line Regions (LINERs).

Phenomenologically, it is unclear why AGNs come in different types. Based on spectral variation, the Narrow Line Region (NLR) is thought to be located farther out from the central Black Hole accretion disk than the Broad Line Region (BLR), and to be spatially much more extended. Within the unification model (Antonucci 1993), which assumes all AGNs to be intrinsically the same, the BLR in NLAGNs is hidden behind an optically thick torus of gas and dust. Consistent with this model, many observations of NLAGNs have revealed hidden BLRs through polarized spectroscopy (Antonucci 2002). However, not all NLAGNs observed with this technique have shown such structures (Tran 2001, 2003; Laor 2003; Shu et al. 2007), suggesting that in some NLAGNs the BLR might simply be absent. This last finding is consistent with alternative models in which the accretion rate and, consequently, AGN luminosity plays a direct role in determining the presence of the BLR (Nicastro 2000; Nicastro et al. 2003; Elitzur & Shlosman 2006).

One possible way how to solve this dilemma is to explore the connection of AGNs with their environment. According to the unification model, for example, one does not expect to find any differences in the number of AGNs in different environments. Unfortunately, such studies are usually controversial. While some authors found Sy2 to inhabit richer environments than Sy1 (de Robertis et al. 1998), others claimed the opposite (Schmitt 2001, and references therein). Recently, Koulouridis et al. (2006) have found no differences in the environment of Sy1 and Sy2 over large scales ($\lesssim$ 1 Mpc), but a higher fraction of Sy2 with close companion than Sy1 in systems with spatial scales smaller than 100 kpc (using H_0=70 km s^{-1} Mpc^{-1}). These results agree with Sorrentino et al. (2006) who found two times more Sy2 than Sy1 in local ($\lesssim$ 100 kpc) environment.

To explore further the possible conection between AGN activity and environment we have undertaken a new survey to determine the nature and frequency of nuclear activity in two different samples of Compact Groups of galaxies (CGs): the Hickson Compact Groups (Hickson 1982, HCGs) and a sample of CGs from the Updated Zwicky Catalog (Focardi & Kelm 2002, UZC-CG). Previous studies on CGs revealed a high percentage of low luminosity AGNs in these structures, but very few luminous ones (Coziol et al. 1998, 2000; Martínez et al. 2006, 2007). Having in hand a statistically significant sample of CGs with complete information on the nuclear activity of their members, allows us to better quantify the frequency of BLAGNs in these systems.

2. Data and Results

Among the HCGs, we have selected the groups with redshifts $z \leq 0.045$, having a surface brightness $\mu_G \leq 24.4$. These criteria provided us with a statistically complete sample of 283 galaxies in 65 groups. We have obtained medium resolution spectroscopy for 238 of these galaxies. The spectra of 71 galaxies come from previous observations made by Coziol et al. (1998, 2000, 2004). The remaining 167 galaxies were observed by our group using four different telescopes: the 2.5m NOT[1] in "El Roque de los Muchachos" (RM, Spain), the 2.2m in Calar Alto (CAHA[2], Spain), the 2.12m in San Pedro Mártir (SPM, Mexico) and the 1.5m telescope in Sierra Nevada Observatory (OSN, Spain).

For all the galaxies, broad components search and activity classification were done only after template subtraction, to correct for absorption features produced by the underlying stellar population. Detailed of the template subtraction method used can be found in Coziol et al. (1998, 2004). Preliminary results have already been published in Martínez et al. (2007). Complete description of observations, reduction and analysis method will be published elsewhere.

For the UZC-CG sample, we have collected spectra from three spectroscopic archives: the Sloan Digital Sky Survey (SDSS-DR4), the Z-Machine and the FAST Spectrograph Archives. We have found spectra for all the galaxy members of 215 groups (720 galaxies): 210 spectra are from the SDSS, 187 from FAST and 323 from Z-Machine (Martínez et al. 2006). Because the Z-Machine spectra have too low S/N ratios to measure broad components, we restrict our analysis to the 397 spectra found in the SDSS and FAST databases. Spectra from the SDSS survey were template subtracted using Hao et al. (2005, H05) eigenspectra and their PCA method. No correction was applied to the galaxies in the FAST sample, due to the non availability of suitable spectra to be used as templates.

Emission lines were found in 153 of the 238 galaxies in the HCG sample (64%) and 274 of the 397 galaxies (69%) in the UZC-CG sample. The identification of broad components was done by fitting a multi-components Gaussian on the emission lines, using the IRAF task NGAUSSFIT. The FWHM of [SII] (or [OIII] when the [SII] lines were too faint or noisy) have been used to model the narrow components of the H_α and [NII] lines. When a broad fourth component was necessary, it was centered on H_α. A χ^2 criterion, as described in H05,

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was applied to choose the fourth component parameters, establishing in this way its presence and characteristics. Examples of fitting plots for three BLAGNs are shown in Fig 1.

Following Osterbrock (1989) we classified BLAGNs galaxies having FWHM $\geq$ 500 km s^{-1}. Our analysis revealed only 1 BLAGN in the HCG sample and 8 in the UZC-CG sample. For each of these galaxies we give, in Table 1 the FWHM of the broad component and activity classification according to Osterbrock (1989): a Sy1.9 shows a broad component only in H_α, while a Sy1.8 shows also a weak broad component in H_β. None of our BLAGNs are classified as Sy1, Sy1.2 or Sy1.5. Based on our analysis, BLAGNs represent only 1% (1/153) of emission line galaxies in the HCG sample and 3% (8/274) in the UZC-CG one.

To classify NLAGNs we used the diagnostic diagram based on the four most intense emission lines: H_β, [OIII]5007Å , H_α, and [NII]6583Å and criteria similar to those employed by Kewley et al. (2006). Galaxies located above the theoretical maximum sequence for star formation are classified as AGNs. We also distinguished between Sy2 and LINERs using the classical upper limit log([OIII]5007Å/H_β) $<$ 0.4 for LINER. Both CG samples are rich in galaxies having only [NII]6583Å and H_α, we classified these cases as Low Luminosity AGNs (LLAGNs) when log([NII]/H_α)> -0.1 (Coziol et al. 1998; Stasińska et al. 2006).

A summary of the nuclear classification for the AGN galaxies in our two samples are presented in Table 2. For each sample (column 1) we give the number of Sy2, LINERs and LLAGNs (columns 2 to 4), which, put together, constitute the total NLAGN populations. In column 5 we report the fractions of BLAGNs over NLAGNs and in column 6 the fraction of Sy1 over Sy2, considering all BLAGNs as Sy1 like.

2.1. Lower ratio of BLAGNs to NLAGNs in CGs than in the field

The fraction of BLAGNs over NLAGNs in our two CG samples is extremely low: 1% for the HCGs and 6% for the UZC-CGs. Also noticeably low are the ratios of Sy1 to Sy2: 4% in the HCG and 19% in the UZC-CG. To realize how low these ratios are one has to compare with what is usually found in other surveys.

The mean H_α luminosity of both NLAGNs and BLAGNs in our two samples is about 10^{39} erg s^{-1}, which is typical of the faint end of the luminosity function of AGNs. This value is comparable with the mean H_α luminosity of AGNs observed in the local universe by Ho et al. (1997a, HFS97). Except for some galaxies in Virgo, all the galaxies in the HFS97 sample are located in low density environments (either loose groups or isolated). In Table 2 we compare their results (395 galaxies, excluding the galaxies in Virgo) with ours. In the HFS97 sample, the BLAGNs were classified as such by Ho et al. (1997b), based on the

detection of a broad H_α component. To be consistent with our definition, all these galaxies were classified as Sy1. Also for comparison sake, the narrow emission lines galaxies in the HFS97 sample were reclassified using the criteria described in sect. 2.

The fraction BLAGN/NLAGN in the HFS97 sample is 22% and the ratio Sy1/Sy2 is 61%. There is consequently a clear deficiency of BLAGNs in CGs. This also appears as an extremely large difference in the number of Sy1 as compared to Sy2 galaxies. This phenomenon is quite intriguing considering that there is no deficit of AGNs as a whole in CGs: 46% AGNs in the HCG, 51% in the UZC-CG compared to 44% in the HFS97 sample.

Comparable ratios (Sy1/Sy2 $\backsim$ 60%) were obtained by Sorrentino et al. (2006, SRR06) in the field, with a slight increase in "loose groups" (Sy1/Sy2 $\backsim$ 69%). In the nearby (z<0.33) sample of SDSS AGN galaxies covering four orders of luminosity and similar environments as SRR06, H05 determined a ratio BLAGN/NLAGN of 43% and a ratio Sy1/Sy2 of 54%. Assuming BLAGNs are slightly favored at higher luminosity these high ratios are comparable to those found by HFS97.

3. Discussion

3.1. Quantifying biases and detection limits

Our results suggest there is an important deficit of BLAGNs in our two CG samples as compared to similar surveys in the field. This result confirm the tendency first encountered by Coziol et al. (1998, 2000). To verify that the lack of BLAGNs in CGs can not be induced by differences in observation, reduction or analysis methods we have investigated thoroughly these possibilities.

Comparison of the UZC-CG sample with the survey made by H05 is safe, because our SDSS data derive from the same telescope, reduction and analysis methods (including template subtraction) as theirs. The ratio BLAGN/NLAGN is 8% in our sample compared to 43% for the sample of H05, which is already a huge difference.

A possible effect due to difference in spectral resolution can also be excluded. Ho et al. (1997b) have used high resolution (2.5 Å) spectra, but made tests with two others low resolution set-ups (5Å and 10Å) obtaining similar results. These are comparable to our own observations: CAHA and OSN (4Å), NOT and SPM (8Å), SDSS (3.5Å) and FAST (6Å). Both H05 and SRR06 have 3.5Å.

The S/N continuum levels of the different surveys are also comparable. On average the S/N of AGNs in our spectra is 60 with a maximum of the order of 120. This is comparable

to H05 and SRR06 spectra (they both used SDSS). HFS97 did not published their values. However their BLAGNs rates are comparable to those of H05 and SRR06, suggesting this is not an issue.

There is no evidence either for a higher galaxy contamination (the amount of galaxy falling into the aperture) in our samples. Taking into account the slit aperture and distances of the host galaxies in each sample we find medians of 1 kpc and 1.3 kpc for the HCG and UZC-CG, respectively. Although the median for HFS97 is lower (0.5 kpc) than for H05 (7 kpc) the results are similar. Obviously, template subtraction (like we also did) alleviates the differences. We may note also that no relation is observed, in any of these surveys (including ours), between the frequency of BLAGNs and the redshift of the galaxies where they are found, which means that nearby galaxies are not more likely BLAGNs than remote ones.

To test if our low number of Sy1 could be due to a difference in morphologies (Schmitt 2001), we have divided our two samples and the HFS97 one in three morphology classes: E for early-type galaxies (E-S0), Se for early-type spirals (S0a-Sbc), and Sl for late-type spirals (Sc and later). For homogeneity sake, all the morphologies have been taken from the Hyperleda database (Paturel et al. 2003). In Table 3 we give for each morphology class the fraction of galaxy and the ratios BLAGN/NLAGN and Sy1/Sy2. There are no BLAGNs in late-type spirals in any sample. In the HFS97 sample, the ratio of BLAGN/NLAGN is marginally higher in the E class while the ratio Sy1/Sy2 is significantly higher, which indicates a definitive increase in BLAGNs in early-type galaxies. In the two CG samples we almost see an inverse trend: the ratios of BLAGN/NLAGN and Sy1/Sy2 are both larger in the Se class than in the E one. Moreover there is a definite rise in the number of early-type galaxies in CGs. Following the HFS97 trend, this should have produced more BLAGNs in CGs instead of less. This eliminates a difference in morphologies as a possible explanation.

We also reject the hypothesis of lower sensitivity. Comparing the median luminosity in Hα of the different types of galaxies in our samples with those in the HFS97 sample, lower sensitivity would have translated into higher values in our samples. This is not observed. In the HFS97 sample the median Hα luminosity of the NLAGNs is $\log(L_{H\alpha} = 38.72$ ergs s^{-1}). Our values are comparable: 38.69 for the HCG and 38.79 for the UZC-CG.

Finally we have determined the detection limits in our samples as in Ho et al. (1997b). Different simulations were performed adding to each set-up spectra a grid of synthetic spectra with broad gaussian components of various widths and amplitudes centered on Hα. We then applied our template and extraction analysis to deduce the following limits. For the CAHA and OSN spectra, broad components equivalent to 15% or higher of the total blended flux in Hα+[NII] were recovered. Using medians of AGN blended flux and redshfit this transforms into a detection limit in Hα broad luminosity of 3.5×10^{38} ergs s^{-1}. We find slightly higher

fraction (20%) for the NOT and SPM spectra, equivalent to a detection limit in luminosity of 4.0×10^{38} ergs s^{-1}. Only three BLAGNs in the HFS97 sample have a luminosity lower than these limits. Obviously, the lack of BLAGNs encountered in our samples cannot be explain by a higher detection limits in our samples.

There seem to be no obvious observational biases or differences in reduction and analysis methods capable of reproducing the lack of BLAGNs in CGs as compared to lower density environments. It is consequently reasonable to conclude that this phenomenon must be related to the environment typical of CGs.

3.2. The disappearance of BLRs in CGs

In the unification model for AGNs, a torus of matter is assumed to be responsible for hiding the BLR from the observer. To be consistent with our analysis, this mechanism should be much more efficient in CGs. However, this assumption goes against the evidence of tidal stripping: in CGs the infall of gas in the disk seem to be stopped, generally diminishing the amount of star formation (Coziol et al. 1998, 2000; Verdes-Montenegro et al. 2001; de la Rosa et al. 2007; Durbala et al. 2008). At the same time, the number of early-type galaxies in CGs is observed to increase. Therefore, a possible reason why no BLRs appear in AGNs in CGs may be because any amount of gas that has reached the center was consumed into stars, building larger bulges (de Carvalho & Coziol 1999). Alternatively, the bulges of galaxies in CGs may have grown without gas, through dry mergers (Coziol & Plauchu-Frayn 2007).

The fact that the average luminosity of the AGNs in CGs is low is another argument in favor of the dissolution hypothesis for the BLR. According to recent results obtained by reverberation mapping, the size of the BLR in AGNs is correlated to the optical luminosity at 5100Å (Kaspi et al. 2005). It is consequently possible to imagine the size of the BLR shrinking almost to zero at some low threshold luminosity (Elitzur & Shlosman 2006). The luminosity at 5100Å in our samples range from $\log(\lambda L_\lambda(5100\text{Å}))$ 40.7 to 43.1 (in units of erg s^{-1}); comparing with data of Peterson et al. (2004) we are in the lower luminosity part of their distribution, where few objects with broad lines have been observed. We also are at the lower limit where no hidden BLRs have been found (Shu et al. 2007; Bian & Gu 2007). Using the relation $\log(L_{bol}/L_{Edd})$, most of our galaxies are below -1.37, which suggests that broad features may simply not exist in these LLAGNs.

According to Nicastro (2000) and Nicastro et al. (2003) low accretion rates rather than smaller mass black holes are responsible in explaining the absence of BLRs in Low Luminosity

AGNs which is fully compatible with our observations.

4. Conclusion

Based on the above statistics, we confirm that there is a remarkable deficiency of BLAGNs as compared to NLAGNs in CGs. This result suggests that BLRs in AGN CGs are directly affected by tidal or group interaction effects, which make them shrink below detection or completely disappear.

In CGs environment, galaxies are undergoing morphological transformations and the main mechanisms for such transformations are tidal interactions and mergers (Coziol & Plauchu-Frayn 2007). Our analysis suggests that the combined effects of these two mechanisms also result in an important decrease in the amount of gas that can reach the nucleus to form a BLR in AGNs.

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REFERENCES

Antonucci, R. 1993, ARA&A, 31, 473

Antonucci, R. 2002, Astrophysical Spectropolarimetry, (Cambridge, CUP), 151 (astro-ph/010348)

Bian, W., & Gu, Q. 2007, ApJ, 657, 159

Caon, N., Capaccioli, M., D'Onofrio, M., & Longo, G. 1994, A&A, 286, 39

Coziol, R., Ribeiro, A. L. B., Capelato, H. V., & de Carvalho, R. R. 1998, ApJ, 493, 563

Coziol, R., Iovino, A., & de Carvalho, R. R. 2000, AJ, 120, 47

Coziol, R., Brinks, E., & Bravo-Alfaro, H. 2004, AJ, 128, 68

Coziol, R., & Plauchu-Frayn 2007, AJ, 133, 2630

de Carvalho, R. R., & Coziol, R. 1999, AJ, 117, 1657

de la Rosa, I. G., de Carvalho, R. R., Vazdekis, A., & Barbuy, B 2007, AJ, 133, 330

de Robertis, M. M., Yee, H. K. C., & Hayhoe, K. 1998, ApJ, 496, 93

Durbala, A., et al. 2008, AJ, 135, 130

Elitzur, M., & Shlosman, I. 2006, ApJ, 648, L101

Focardi, P., & Kelm, B. 2002, A&A, 391, 35

Hao, L., et al. 2005, AJ, 129, 1783 (H05)

Hickson, P. 1982, ApJ, 255, 382

Hickson, P., Kindl, E., & Huchra J. P. 1988, ApJ, 331, 64

Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1997a, ApJS, 112, 315 (HFS97)

Ho, L. C., Filippenko, A. V., Sargent, W. L. W., & Peng, C. Y. 1997b, ApJS, 112, 414

Kaspi, S., Maoz, D., Netzer, H., Peterson, B. M., Vestergaard, M., & Jannuzi, B. T. 2005, ApJ, 629, 61

Kewley, L. J., Groves, B., Kauffmann, G., & Heckman, T. 2006, MNRAS, 372, 961

Koulouridis, E., Plionis, M., Chavushyan, V., Dultzin-Hacyan,D., Krongold, Y., & Goudis, C. 2006, ApJ, 639, 37

Laor, A. 2003, ApJ, 590, 86

Martínez, M. A., del Olmo, A., Focardi, P., & Perea J. 2006, VII Scientific Meeting of SEA (astro-ph/0611099)

Martínez, M. A., del Olmo, A., Perea, J., & Coziol, R. 2007, ESO Astro. Symp., Springer-Verlag, 163

Mendes de Oliveira, C., & Hickson, P. 1994, ApJ, 427, 684

Nicastro, F. 2000, ApJ, 530, L65

Nicastro, F., Martocchia, A., & Matt, G. 2003, ApJ, 589, L13

Osterbrock, D. E. 1989, in Astrophysics of Gaseous Nebulae and Active Galactic Nuclei, University Science Books

Paturel, G., et al. 2003, A&A, 412, 45

Peterson, B. M., et al. 2004, ApJ, 613, 682

Peterson, B. M., et al. 2005, ApJ, 632, 799

Shu, X. W., Wang, J. X., Jiang, P., Fan, L. L., & Wang, T. G. 2007, ApJ, 657, 167

Schmitt, H. R. 2001, AJ, 122, 2243

Sorrentino, G., Radovich, M., & Rifatto, A. 2006, A&A, 451, 809 (SRR06)

Stasińska, G., Cid Fernandes, R., Mateus, A., Sodré, L., & Asari, N. V. 2006, MNRAS, 371, 972

Tran, H. D. 2001, ApJ, L554, 19

Tran, H. D. 2003, ApJ, 583, 632

Verdes-Montenegro et al. 2001,A&A, 377, 812

Table 1. BLAGNs identification

Name	Source	Type	FWHM(H_α) (km/s)	FWHM(H_β) (km/s)
HCG 5a	CAHA	1.9	1056	···
UZC-CG 84c	SDSS	1.9	2727	···
UZC-CG 89b	SDSS	1.9	2159	···
UZC-CG 109b	SDSS	1.8	1902	1499
UZC-CG 117a	SDSS	1.9	2351	···
UZC-CG 132b	FAST	1.9	3055	···
UZC-CG 139b	SDSS	1.9	1941	···
UZC-CG 232c	SDSS	1.8	2258	1689
UZC-CG 234b	FAST	1.9	1328	···

Table 2. Nuclear classification for the AGN galaxies

Sample	NLAGN			BLAGN	$\frac{\mathrm{BLAGN}}{\mathrm{NLAGN}}$	$\frac{\mathrm{Sy1}}{\mathrm{Sy2}}$
	Sy2	LINER	LLAGN		%	%
HCG	28	23	19	1	1	4
UZC-CG	43	11	79	8	6	19
HFS97	46	80	···	28	22	61
H05	2424	650	···	1317	43	54
SRR06	1104	···	···	725	···	66

Table 3. Activity types and morphological distribution

Sample	E-S0			S0a-Sbc			Sc-Irr
	f_E	$\frac{\mathrm{BLAGN}}{\mathrm{NLAGN}}$	$\frac{\mathrm{Sy1}}{\mathrm{Sy2}}$	f_{Se}	$\frac{\mathrm{BLAGN}}{\mathrm{NLAGN}}$	$\frac{\mathrm{Sy1}}{\mathrm{Sy2}}$	f_{Sl}
HCG	54%	···	···	32%	3%	10%	14%
UZC	34%	2%	8%	55%	9%	25%	11%
HFS97	25%	25%	86%	39%	19%	56%	36%

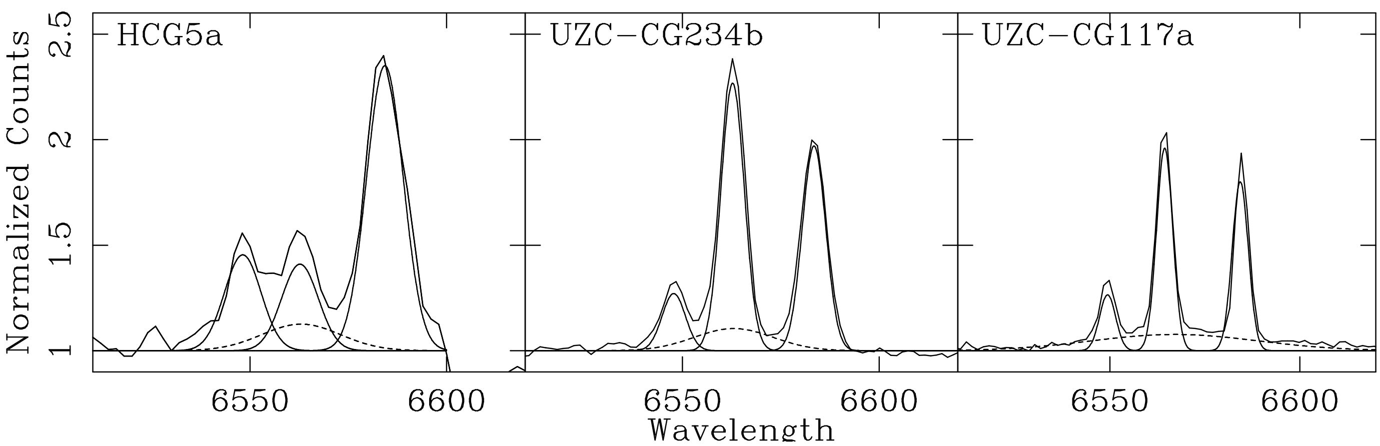

Fig. 1.— Examples of BLAGNs in our sample with multi-components Gaussian decompositions centered on Hα.